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REDISCOVERY OF *ANACAMPSIS LUPINELLA* BUSCK (LEPIDOPTERA: GELECHIIDAE) IN ONTARIO

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Abstract *J. ent. Soc. Ont.* 151: 1–14

We rediscovered populations of *Anacampsis lupinella* Busck (Lepidoptera: Gelechiidae) in three remnant populations of sundial lupines (*Lupinus perennis* L. (Fabaceae)) in southern Ontario. Here we provide a detailed description of the species and illustrate it with figures of adult moths and both male and female genitalia. Photographs of the moths taken recently in High Park, Toronto, match photos of the type specimen that was collected at High Park in 1901. The male genitalia of contemporary males match those of a male from the original series of specimens collected in Toronto. CO1 DNA barcodes of eight contemporary specimens were very similar to the CO1 barcode recovered from a specimen from the original series. The CO1 sequences demonstrated slight genetic differentiation of the three Ontario populations, but collectively were clearly delimited from the seven congeneric species known from Ontario.

Introduction

In early June of 1900, larvae of an unknown moth were discovered feeding on sundial lupines, *Lupinus perennis* L. (Fabaceae), in High Park, Toronto, by amateur

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entomologist Allan Kinghorn. He sent several larvae and lupine cuttings to Dr. James Fletcher, the Dominion Entomologist at the Central Experimental Farm in Ottawa, who reared and mounted them. Fletcher then sent three specimens to August Busck, a noted microlepidopterist of the Bureau of Entomology of the US Department of Agriculture in Washington, D.C., who described them as a new species, *Anacampsis lupinella* Busck. Fletcher retained one specimen, which is now in the Canadian National Collection. Those were the only specimens of *A. lupinella* collected in Canada until recently.

Little is known about *A. lupinella*. In addition to the type locality it has been reported from scattered localities in Illinois, Ohio, eastern Texas, Louisiana, the Florida Panhandle (Moth Photographers Group 2019), and Maryland (BugGuide.net). However, there is no indication of how these records were identified and where vouchers, if they exist, are preserved. Forbes (1923, pp. 277–279) briefly described the adult and larva and summed up what is known of the life history as "[larva] in a slight web between leaves of lupine". Both *A. lupinella* and its host plant, the sundial lupine (*Lupinus perennis*), are of conservation concern in Canada. The national (and provincial) conservation status ranks are S1S3 (critically imperiled to vulnerable) for the moth and S2S3 (imperiled to vulnerable) for the plant (NatureServe 2019).

After more than 100 years, *A. lupinella* has been rediscovered in remnant populations of sundial lupine in three different locations within Ontario (Fig. 1). In this

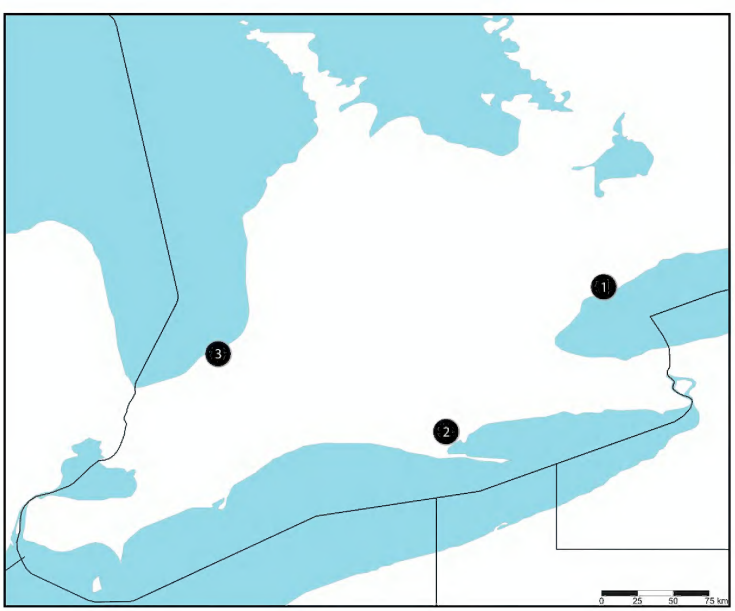

FIGURE 1. Map of Southwestern Ontario showing the three known Canadian localities of *Anacampsis lupinella*: 1) High Park, Toronto, York Region, 2) St. Williams Conservation Reserve, Norfolk County, and 3) Lambton Shores, Lambton County.

paper we describe these discoveries, provide a diagnosis of the species, and provide DNA barcode data for all species of *Anacampsis* Curtis (Gelechiidae: Anacampsinae) known from Ontario.

Rediscovery of *Anacampsis lupinella*

High Park, Toronto, York Region

In 2016, DB and Richard Aaron searched sundial lupines for *A. lupinella* in High Park (43.648N, 79.467W), the type locality for the species. High Park has a small population of sundial lupines (9120 lupine inflorescences when evaluated in 2014; Jarvis 2015), a tiny remnant of the extensive fields of lupines that existed near Toronto in the early 1900s. On 6 July, under hot sunny conditions, their first sweep through lupines yielded moths that matched the description of *A. lupinella* and were recorded in photos (e.g., https://www.inaturalist.org/observations/14227954). In total, they caught four individuals that exhibited the full range in coloration known for the species (as described below). Two years later, on 18 July 2018, R. Aaron, Taylor Leedahl, Ken Sproule, and DB spent several hours sampling all of the lupine patches in the park. Under excellent weather conditions—light winds, moderate humidity, >20°C, and thin high haze—they netted ~50 specimens of *A. lupinella* that they released after capture.

St. Williams Conservation Reserve, Norfolk County

During a visit to the Manestar Tract of the St. Williams Conservation Reserve (42.700N, 80.461W) on 8 June 2017, MG, GWO, Peter Carson, and Jessica Linton noticed numerous "leaf nests" on lupines. Sundial lupines are known to have existed in this region for as long as there have been records of the vegetation of Norfolk County (Draper *et al.* 2002). Constructed by a single moth larva, each "leaf nest" consisted of 2–3 lobes of a lupine leaf webbed together. Being aware of the rediscovery of what were likely *A. lupinella* moths in Toronto, they immediately performed a Google search and found images of *A. lupinella* larvae on sundial lupine from Maryland that visually matched the larvae and leaf nests at the Manestar Tract (BugGuide 2019).

MG returned to the Manestar Tract on 1 July 2017 and observed numerous small adult moths among the lupines. She immediately applied for and received a permit from the Ontario Ministry of Natural Resources and Forestry to collect specimens. On the afternoon of 6 July she made 200 back-and-forth sweeps with an aerial insect net over lupine plants and caught 181 adult moths. Six specimens collected from the Manestar Tract and two from roadside plants ~2 km north along Concession 7/Walshingham Townline were mounted by Jim Troubridge and submitted to the Canadian National Collection in Ottawa for identification. On 7 July of the following year, adult moths were again present but were less abundant. Searches by MG at former agricultural fields 2–3 km away that have been restored with sundial lupines and other native species failed to detect this species.

Lambton Shores, Lambton County

Historically, the northernmost region of Lambton County, from Pinery Provincial Park and Port Franks east to Thedford, harbored extensive oak savanna habitat with large populations of sundial lupines. Agriculture, human settlement, lack of savanna management including suppression of fires, and the unfortunate planting of pine trees within Pinery Provincial Park greatly reduced lupine populations and their savanna habitat. As a consequence, a number of species of Lepidoptera have become rare or, like the lupine-feeding Karner blue (*Lycaeides melissa samuelis* Nabokov), Frosted Elfin (*Callophrys irus* (Godart)), and Eastern Persius Duskywing (*Erynnis persius persius* (Scudder)), extirpated from the region.

In 2017, MG encouraged KS to search for lupine moths by sweeping a net back and forth over lupines in this region. On 9 July 2018, KS caught 8–10 individuals in each sweep of the net within lupines at the Karner Blue Sanctuary (KBS; 43.222N, 81.887W) in Port Franks, a 15 ha property acquired by Lambton Wildlife Inc. to protect its rare habitats. He retained 12 specimens, two of which were barcoded at the Centre for Biodiversity Genomics (CBG), University of Guelph (specimen # CNCLEP00208671 and CNCLEP00208672). On a return visit to KBS on 16 July he observed only 3–4 adult moths. KS also swept lupines and caught a few *A. lupinella* moths at a site on Goosemarsh Line near the southeastern boundary of Pinery Provincial Park (43.239N, -81.830W) that has small and declining numbers of lupines. No moths were found near the Riverside Campground, near the southwestern corner of Pinery Provincial Park, in a habitat that was burned in 2008 and has a moderate number of lupines.

Results and Discussion

Specimen Identification: Adult morphology

Specimens from both Manestar Tract and Port Franks have been deposited in the CNC in Ottawa (refer to Table 1 for details of specimens). JFL examined morphological characters, including male and female genitalia, and compared them to specimens of various species of *Anacampsis* in the CNC. The male genitalia of the recently collected moths matched those of the male specimen from the original series of *A. lupinella* reared by Fletcher.

Although the sampled specimens were only compared to a photograph of the actual type specimen (type # 5351, deposited in the National Museum of Natural History, Washington, D.C., and photographed during a visit by JFL in 2004), we consider that the morphological match with a specimen from the original reared series from which the type was selected positively confirms the identity of the moths reared on lupines in Norfolk County as *Anacampsis lupinella*. Other species of *Anacampsis* recorded from Ontario, namely *A. agrimoniella* (Clemens), *A. conclusella* (Walker), *A. consonella* (Zeller), *A. niveopulvella* (Chambers), *A. populella* (Clerck), *A. rhoifructella* (Clemens), and *A. tristrigella* (Walsingham) are easily distinguished from *A. lupinella* by their external aspect (photos of the various species can be seen in the BOLD taxonomy browser: http://v4.boldsystems.org/index.php/TaxBrowser_Home).

In phenotypic appearance, adults of *A. lupinella* have the upper surface greyish

TABLE 1: Data for specimens of *Anacampsis lupinella* examined in this study and deposited in the CNC. BOLD Process ID = sequence identifier in the Barcode of Life Data System. This material represents the entire CNC holdings for this species.

Specimen ID	BOLD Process ID	Sequence Length	Dissection	Sex	Locality	Latitude	Longitude	Collecting Date	Collector
CNCLEP00100647	NGSFT2078-16	439	–	M	Toronto	–	–	18 Jul 1900	Allan Kinghorn
CNCLEP00175634	MNAR907-17	658	MIC 8074	M	Manestar Tract	42.7076	-80.3575	6 Jul 2017	Mary Gartshore
CNCLEP00175635	MNAR908-17	658	MIC 8075	F	Manestar Tract	42.7076	-80.3575	6 Jul 2017	Mary Gartshore
CNCLEP00175636	MNAR909-17	658	–	F	Manestar Tract	42.7076	-80.3575	6 Jul 2017	Mary Gartshore
CNCLEP00175637	MNAR910-17	658	–	F	Manestar Tract	42.7076	-80.3575	6 Jul 2017	Mary Gartshore
CNCLEP00175638	MNAR911-17	658	–	M	Manestar Tract	42.7076	-80.3575	6 Jul 2017	Mary Gartshore
CNCLEP00175639	MNAR912-17	658	–	F	Manestar Tract	42.7076	-80.3575	6 Jul 2017	Mary Gartshore
CNCLEP00175885	–	–	–	F	Port Franks	43.2314	-81.8903	9 Jul 2018	Ken H. Stead
CNCLEP00175886	–	–	–	F	Port Franks	43.2314	-81.8903	9 Jul 2018	Ken H. Stead
CNCLEP00175887	–	–	–	F	Port Franks	43.2314	-81.8903	9 Jul 2018	Ken H. Stead
CNCLEP00175888	–	–	–	F	Port Franks	43.2314	-81.8903	9 Jul 2018	Ken H. Stead
CNCLEP00175889	–	–	–	F	Port Franks	43.2314	-81.8903	13 Jul 2018	Ken H. Stead
CNCLEP00175890	–	–	–	M	Port Franks	43.2314	-81.8903	13 Jul 2018	Ken H. Stead
CNCLEP00175891	–	–	–	M	Port Franks	43.2314	-81.8903	13 Jul 2018	Ken H. Stead
CNCLEP00175892	–	–	–	F	Port Franks	43.2314	-81.8903	13 Jul 2018	Ken H. Stead
CNCLEP00208671	KSLEP1177-18	658	–	F	Port Franks	43.2314	-81.8903	13 Jul 2018	Ken H. Stead
CNCLEP00208672	KSLEP1178-18	658	–	F	Port Franks	43.2314	-81.8903	13 Jul 2018	Ken H. Stead

black and the ventral surface grey. The forewing length is 5.4–6.2 mm (mean = 5.7, N = 18). The forewing surface has a dark, blackish brown ground color with a slightly iridescent sheen in bright light (Fig. 2). In most specimens, the forewing has a pair of elongate yellowish-white spots in the distal third, one before the apex, the other opposite near the termen (10/17 examined) (Fig. 3A); in some specimens, the spots are variously connected with a narrow transverse fascia of the same color (3/17 examined); some specimens have uniformly dark brown forewings without pale marks (4/17 examined) (Fig. 3B). Under magnification, three or four smaller black spots can be discerned in the middle (discal) area of the forewing (more distinct in old, faded specimens). In the original description, Busck (1901) described the variation in the forewing pattern. This variation is not sex-related, as evidenced by variants being represented among both males and females. The hindwing is dark blackish brown. The eyes are dark red (Fig. 3C), a characteristic shared by several other *Anacampsis* species. The labial palpi are tan-colored, sickle-shaped, with the third segment acicular, longer than the second segment, and extended well above the level of vertex with an infuscated tip. Old specimens in collections can be somewhat faded and appear grey brown, especially the basal two-thirds of the forewing preceding the white fascia. In such specimens the dark discal spots are more evident against the surrounding background (Fig. 3D).

FIGURE 2. Photograph of a live *Anacampsis lupinella* taken at the Manestar Tract, Norfolk County, by Mary Gartshore.

FIGURE 3. *Anacampsis lupinella* (A) female showing forewing with distal white fascia (specimen CNCLEP00175887), (B) female showing forewing without distal fascia (specimen CNCLEP00175889), (C) head, lateral view, showing dark red eye and tan-colored, sickle-shaped labial palpi (specimen CNCLEP00175889), (D) female (specimen CNCLEP00100647) from original reared series from Toronto in 1900, similar to the type specimen in the Smithsonian National Museum of Natural History.

Forbes (1923, p. 279) briefly diagnosed the larva as dull green with a testaceous head and a black spot on each side near the eyes, and indicated that it lives in "a slight web between leaves of lupine". No other descriptions of the immature stages have been published.

Anacampsis lupinella externally resembles some species of *Aproaerema* Durrant (Gelechiidae: Anacampsinae) in the dark brown forewing with a distal, transverse pale fascia. However, *Aproaerema* species with a similar forewing pattern in the CNC examined by JFL are distinctly smaller on average than *A. lupinella*. Additionally, members of *Anacampsis* have the termen of the hindwing rounded and indistinctly sinuate. In contrast, members of *Aproaerema* have the termen of the hindwing markedly sinuate ending in a sharp point.

One unidentified (and possibly undescribed) *Aproaerema* species from southern Alberta in the CNC and similar in coloration to *A. lupinella* was reared from larvae tying together leaves of a lupine (*Lupinus argenteus* Pursch). Species of *Aproaerema* with known

host plants all feed upon species within the family Fabaceae. Species of *Anacampsis*, at least those related to the type species (i.e. *A. populella* (Clerck)), are predominantly known to be oligophagous or monophagous on trees, shrubs, and herbaceous plants of various families, including Adoxaceae, Betulaceae, Cistaceae, Fabaceae, Fagaceae, Rosaceae, and Salicaceae (Bland *et al*. 2002; Robinson *et al*. 2002). To date, *A. lupinella* larvae and adults have only been reported in association with sundial lupine.

Examination of genitalia by JFL of all the above-mentioned species as well as several others not recorded from ON (*A. psoraliella* Barnes & Busck, *A. lacteusochrella* (Chambers), *A. fragariella* Busck, *A. pasadenae* Keifer) showed both sexes of *A. lupinella* to be distinct in the shape and relative size of several structures. Diagnostic combinations of genitalic characters for each sex are as follows.

In the male (Fig. 4): uncus with the dorsal surface evenly rounded, the distal half roundly conical, the ventral surface covered with 15–20 peg-like sensilla on each side and divided by a narrow mesial gap; gnathos without ventrally protruded mesial process; tegumen elongate, almost 2 × as long as wide, with sides nearly straight and barely concave anteriorly (ventral aspect); cucullus of valva distally spatulate, barely extended beyond apex of uncus; vinculum with anterior margin not extended beyond apex of pedunculi of tegumen and broadly rounded, without saccus (lateral aspect); juxta with apex mesially U-emarginate, making it to appear bilobate (ventral aspect), sides anteriorly concave and narrowed, in lateral aspect distally slightly downcurved and tapered, extended to ¾ of cucullus; phallus sigmoid in lateral aspect, ventral margin medially angulate, apically tapered, in ventral aspect nearly straight with slight constriction at phallobase which is about 0.4 length of phallus; cornuti absent.

In the female (Fig. 5): projection of posterior margin of tergum 8 narrowly digitiform in dorsal aspect, flat and wedge-like in lateral aspect; sternum 8 divided into two subtriangular plates separated by a membranous, longitudinally wrinkled sinus vaginalis which is about 0.5 × width of sternum; ostium bursae ventrally bordered by thin, weakly sclerotized transverse band; distal third of ductus bursae membranous, gradually widened to ostium bursae, anteriorly extended to anterior apex of anterior apophyses; corpus bursae elongate-ovoid, 1.8 × as long as wide, with a constriction anterior to signum, surface sparsely spiculate, except for area surrounding the signum with a smooth membrane; signum a thin, transverse, finely spinulate, zipper-like band; accessory sac subspherical, about a third the size of corpus bursae.

The other *Anacampsis* species differ variously in shape and size of several or all of these characters. They are not shown here as it is beyond the scope of this paper. Illustrations are found in Harrison and Berenbaum (2013, 2014) for *A. consonella*, *A. psoraliella*, *A. rhoifructella*, and *A. wikeri* Harrison.

The genus *Anacampsis* is quite large, comprising over 150 described species, with the greatest diversity in the Neotropics (Karsholt & Riedl 1996; Ponomarenko 2008; Lee 2009). Twenty-four species are known from North America (Lee *et al*. 2009; Harrison and Berenbaum 2013, 2014), 12 are recorded from Canada and 8 from Ontario (Pohl *et al*. 2018). There are no taxonomic revisions of *Anacampsis* or of other genera of Anacampsinae, and the delineation of included genera is unclear. There are no good and unique external characters that allow unequivocal recognition of members of *Anacampsis*, and consequently micro-dissections and examination of genitalia are required to achieve positive identification. Even

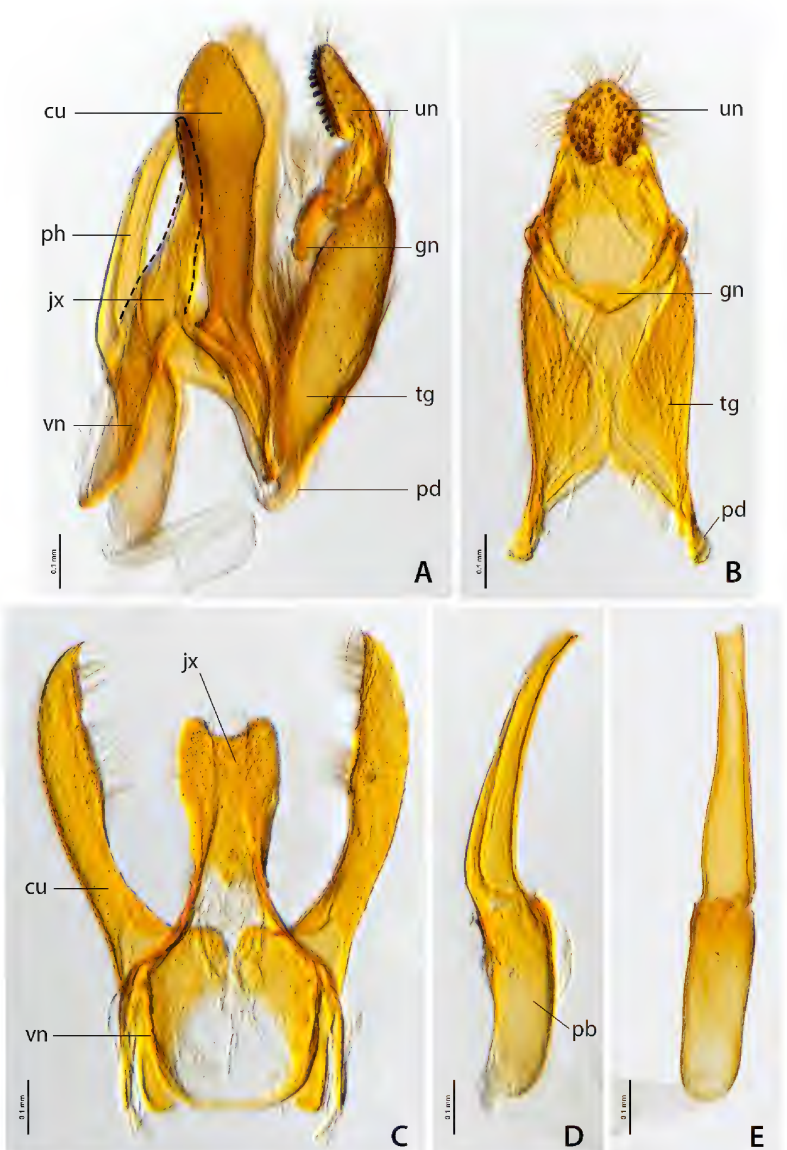

FIGURE 4. Male genitalia of *Anacampsis lupinella*: (A) intact genitalia, lateral aspect, (B) tegumen, uncus, gnathos, ventral aspect, (C) vinculum, juxta, cucullus, ventral aspect, (D) phallus, lateral aspect, (E) phallus, ventral aspect. Abbreviations: cu = cucullus (of valva); gn = gnathos; jx = juxta; pb = phallobase; pd = pedunculus of tegumen; ph = phallus; tg = tegumen; un = uncus; vn = vinculum.

FIGURE 5. Female genitalia of *Anacampsis lupinella*: (A) corpus bursae, accessory sac, abdominal segment 8 and ducti, ventral aspect, transmitted light with dark background, (B) detail of corpus bursae and signum, (C) sternum 8, ventral aspect, (D) tergum 8, dorsal aspect, (E) tergum 8, lateral aspect. Abbreviations: aa = apophysis anterior; ap = apophysis posterior; as = accessory sac; cb = corpus bursae; db = ductus bursae; ds = ductus seminalis; ob = ostium bursae; pap = papillae anales; pT8 = posterior projection of tergum 8; sig = signum; sm = smooth area of ductus bursae; sv = sinus vaginalis; S8 = sternum 8; T8 = tergum 8; wT8 = wall of tergum 8.

the current (traditional) inclusion of several species in *Anacampsis* (e.g., Hodges 1983; Lee *et al*. 2009) appears questionable; an assessment of genitalia and DNA barcodes among 18 of the North American species, conducted by JFL in preparation of this paper, revealed that several of these (*A. conclusella* (Walker), *A. covardalella* (Kearfott), *A. fullonella* (Zeller), *A. levipedella* (Clemens), *A. paltodoriella* (Busck)) have genitalic configurations that differ markedly from the type species *A. populella* and related species like *A. lupinella*, and thus probably belong to other genera, either described or undescribed.

Species identification from external features can be challenging as several species of *Anacampsis* display variation in coloration and wing pattern. Moreover, species boundaries have never been re-examined nor have the genitalia of most species been characterized; their original descriptions were based solely on external features such as coloration and shape of the wings and labial palps. Conversely, different species may have confusingly similar adults but different, very distinct larvae. As a case in point, recently the status and distinction of two common species were shown to have been historically conflated and erroneously synonymized and their host plant mistakenly attributed (Harrison and Berenbaum 2014). It is notable that no new species of *Anacampsis* were described from North America between 1933 and 2013 (see Harrison and Berenbaum 2013), possibly because the cryptic nature of recently described species necessitates careful study of internal morphology and life histories, now supplemented by DNA evidence.

DNA barcode analysis

Tissue samples were sent to the CBG for further confirmation through DNA barcoding. Firstly, the single remaining specimen in the CNC (CNCLEP00100647) reared by Fletcher in 1900 was DNA-barcoded using protocols designed for recovering the barcode region of the cytochrome oxidase 1 (COI) gene from the degraded DNA of legacy specimens (Prosser *et al*. 2016). The eight contemporary specimens were DNA barcoded with standard protocols that target the entire COI barcode fragment (deWaard *et al*. 2019). The sequences generated were compared with DNA barcodes for the seven other *Anacampsis* species recorded from Ontario (Pohl *et al*. 2018).

The COI barcodes of the eight recently collected specimens were a close match (0.93–1.40% Kimura-2-parameter distance) to the Fletcher specimen, further confirming their identity. They revealed a geographic pattern consistent with three isolated populations that differ slightly from each other (Fig. 6). Additionally, *A. lupinella* sequences were clearly delimited from the seven congeneric species known from Ontario (Fig. 6). All records are available on the Barcode of Life Data System (http://www.boldsystems.org) in the public dataset 'DS-ANACAM19' (http://dx.doi.org/10.5883/DS-ANACAM19) and have been submitted to GenBank (see BOLD dataset for GenBank accessions).

We find it interesting that *A. lupinella* has persisted in Ontario in relatively small, isolated populations of lupines. In contrast, other lupine-specialist species such as the Karner Blue, Frosted Elfin, and Eastern Persius Duskywing butterflies have become extirpated in Canada (Environment and Climate Change Canada 2017). It is unclear why *A. lupinella* has not yet been observed in sites with restored lupine habitat in relatively close proximity to extant populations.

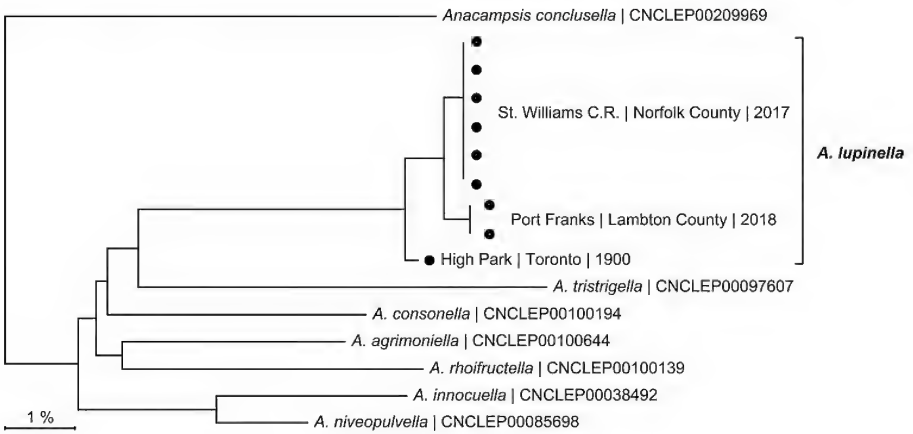
Anacampsis conclusella | CNCLEP00209969
St. Williams C.R. | Norfolk County | 2017
A. lupinella
Port Franks | Lambton County | 2018
High Park | Toronto | 1900
A. tristrigella | CNCLEP00097607
A. consonella | CNCLEP00100194
A. agrimoniella | CNCLEP00100644
A. rhoifructella | CNCLEP00100139
A. innocuella | CNCLEP00038492
A. niveopulvella | CNCLEP00085698
1 %

FIGURE 6. DNA barcode neighbor-joining tree for *Anacampsis lupinella* and seven congeneric species in Ontario (scale bar = divergence of 1% using Kimura-2-parameter distances). The three Ontario populations show slight differences, suggesting they are genetically isolated from each other.

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EMBLEMASOMA ALBICOMA REINHARD (DIPTERA: SARCOPHAGIDAE), A PARASITOID OF *NEOTIBICEN CANICULARIS* (HARRIS) (HEMIPTERA: CICADIDAE) IN ONTARIO, CANADA

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The New World genus *Emblemasoma* Aldrich (Diptera: Sarcophagidae) is an acoustic parasitoid of cicadas (Hemiptera: Cicadidae) and includes 16 species (Pape 1996). These flies locate their adult cicada hosts by homing in on the mating call, attacking both stationary and flying cicadas (Soper *et al.* 1976; Stucky 2015). They have also been reported as showing an attraction to the recorded calling songs of cicadas (Soper *et al.* 1976; Lakes-Harlan 2009). *Emblemasoma* find their hosts with insect "ears" (present in both sexes), which are sound-sensitive enlarged tympanal membranes near the prosternum and connected to the anterior spiracles (Tron *et al.* 2016).

Prior to this study, host associations were known only for two species of *Emblemasoma*: *E. erro* Aldrich with hosts *Quesada gigas* (Olivier) (Lopes 1971), *Ameritibicen dorsatus* (Say) (Stucky 2015) and *Neotibicen linnei* (Smith and Grossbeck) (Young 2020); and *E. auditrix* (Shewell) with host *Okanagana rimosa* (Say) (Soper *et al.* 1976). Parasitized cicadas are primarily calling males and only occasionally are females parasitized, likely due to their close proximity to a calling male (Stucky 2015; Young 2020). Males of *E. erro* are also attracted to calling male cicadas, around which they then engage in mate-finding behaviour (Stucky 2016). In addition, males of *Emblemasoma* are known to concentrate at hilltops, presumably for mating purposes, as evidenced from specimens of *E. erro* in the Canadian National Collection of Insects, Arachnids and Nematodes (CNC, Ottawa) collected at hilltops.

This study began with the opportunistic collection of a barely-alive male cicada of the species *Neotibicen canicularis* (Harris) in a park in Ottawa, Ontario on 12 August 2013. The specimen was placed in a vial, and after several weeks a dead, shrunken sarcophagid larva was discovered along with the then-dead cicada. No morphological identification of the larva beyond family was possible.

Following this chance discovery of parasitism, similarly lethargic specimens of *N. canicularis* were collected in subsequent years at entrances to the K.W. Neatby Building on the Central Experimental Farm in Ottawa (45°23.5′N 75°42.9′W) during August and early

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September, usually in early morning. These cicadas were held in containers until either parasitoids emerged or the cicadas died.

In 2016, a male cicada was collected in early September and two larvae emerged and pupariated on 20 September, but adult flies failed to emerge following overwintering procedures outlined below. In 2017, a male cicada was collected in mid-August and three larvae emerged on 20 August (Fig. 1), but again adult flies failed to emerge following overwintering. In 2018, a male cicada was collected on 14 August and two larvae emerged and pupariated on 16 August. These puparia were transferred to a small container with potting soil and kept at room temperature until moved to an overwintering chamber held at 22°C (16L:8D). The temperature was lowered to 18°C (12L:12D) on 23 October 2018, then to 8°C (45% RH) on 8 November, and finally to 4°C (60% RH) on 22 November. The chamber was warmed to 18°C (14L:10D) on 17 May 2019 and later to 22°C (16L:8D) on 30 May 2019. After this date the puparia were removed and held at room temperature until a single female adult fly emerged on 4 July 2019 (Fig. 2). All specimens are housed in the CNC. The timing of emergence coincides with the emergence of the cicada hosts in early July in this region.

The parasitoid was identified as *E. albicoma* Reinhard using the identification key to species in Lopes (1988) and by comparison to identified specimens in the CNC. In addition, a leg from the fly was submitted to the Biodiversity Institute of Ontario in Guelph, ON, Canada for sequencing and alignment of the "Barcoding" region (Hebert *et al*. 2003) of the Cytochrome *c* oxidase subunit I (COI) mitochondrial gene, a 658 base-pair region of this gene. A sequence analysis was performed constructing a neighbour-joining tree with all available sequences using the BOLD website (Fig. 3). The author's specimen (CNC1424066) is genetically closest (99.19%) to an *E. albicoma* specimen (JQ806981) collected from an observation tower in Wisconsin by sarcophagid expert Greg Dahlem (Dahlem pers. comm. 2019). The analysis included a male specimen of *E. erro* from Wisconsin, reared from

FIGURES 1 and 2. (1) Puparia of *Emblemasoma* sp., larvae emerged from a male *Neotibicien canicularis* on 20 August 2017; (2) Female of *Emblemasoma albicoma* Reinhard, reared from *Neotibicen canicularis*.

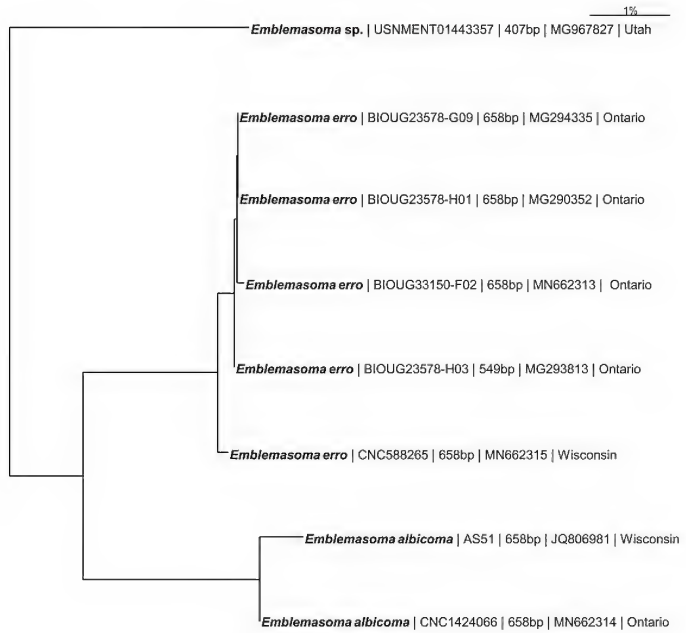
1%
Emblemasoma sp. | USNMENT01443357 | 407bp | MG967827 | Utah
Emblemasoma erro | BIOUG23578-G09 | 658bp | MG294335 | Ontario
Emblemasoma erro | BIOUG23578-H01 | 658bp | MG290352 | Ontario
Emblemasoma erro | BIOUG33150-F02 | 658bp | MN662313 | Ontario
Emblemasoma erro | BIOUG23578-H03 | 549bp | MG293813 | Ontario
Emblemasoma erro | CNC588265 | 658bp | MN662315 | Wisconsin
Emblemasoma albicoma | AS51 | 658bp | JQ806981 | Wisconsin
Emblemasoma albicoma | CNC1424066 | 658bp | MN662314 | Ontario

FIGURE 3. Neighbour-joining tree of *Emblemasoma* with COI sequences, including unique voucher number, sequence length, GenBank accession number and province/state.

N. linnei (Young 2020). This last specimen clustered with four Ontario specimens, one of which was collected in Malaise trap surveys of Ontario provincial parks (Centre for Biodiversity Genomics 2017).

This is the first rearing report and first published Ontario record for *E. albicoma* and for *N. canicularis* as a host. Collection of "stunned" cicadas will continue in the hopes of rearing additional specimens of *Emblemasoma*.

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NEW CANADIAN RECORDS OF *PHYLLOPALUS PULCHELLUS* UHLER AND *HAPITHUS AGITATOR* UHER (ORTHOPTERA: GRYLLIDAE) BASED ON DIGITAL OBSERVATIONS

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In the six years since the checklist of the Orthoptera of Ontario was published (Paiero and Marshall 2014), there has been an increase in the number of posts of Ontario Orthoptera on various online platforms that include observations from the extreme southwestern parts of Ontario where additional species from adjacent regions may be expected to occur. In 2018, observations of two cricket (Orthoptera: Gryllidae) species, *Phyllopalpus pulchellus* Uhler and *Hapithus agitator* Uhler, were posted on iNaturalist.org (2019) from southwestern Ontario and represented new Canadian records. The observations of these two species are discussed and summarized (Table 1) along with a brief discussion on the value of web-based citizen scientist observations.

***Phyllopalpus pulchellus* Uhler – red-headed bush cricket**

This beautiful and distinctive species (Fig. 1A) was initially recorded in Amherstburg, Ontario, on 13 September 2018, and subsequently supported by a previous observation from LaSalle, on 2 September 2018. Both were single individuals and no additional individuals were encountered at either locality. In 2019, additional observations were made in Essex County, including the site of the original observation along with several additional sites around the Windsor area. A female was observed in the Ojibway Prairie Provincial Nature Reserve and taken as a voucher (deposited at the University of Guelph Insect Collection). These additional records suggest that *P. pulchellus* has indeed established itself in Ontario and may be slowly expanding its range. This species was previously expected to occur in Ontario (as noted in Paiero and Marshall 2014) based on records in Ohio, and recent records in Michigan (O'Brien and Craves 2016) suggest this species is slowly expanding its range northward.

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TABLE 1: Summary of digital observations of *Hapithus agitator* Uhler and *Phyllopalpus pulchellus* Uhler from Ontario as of 5 May 2020, including platform, links to original observations, general locations, dates observed and observer.

Species	Platform	Link (if available)	Location	Observation Date	Observer
Hapithus agitator	iNaturalist	https://inaturalist.ca/observations/16722342	Pelee Island	4 September 2018	J.C. Crosthwaite and G.M. Pitman
H. agitator	iNaturalist	https://inaturalist.ca/observations/16722598	Pelee Island	14 September 2018	J.C. Crosthwaite and G.M. Pitman
H. agitator	iNaturalist	https://inaturalist.ca/observations/16798314	Point Pelee National Park	22 September 2018	S.M. Paiero (specimen voucher taken)
H. agitator	iNaturalist	https://inaturalist.ca/observations/17058800	Point Pelee National Park	26 September 2018	M. Kennedy
H. agitator	iNaturalist	https://inaturalist.ca/observations/17337395	Point Pelee National Park	8 October 2018	K. Yukich
H. agitator	iNaturalist	https://inaturalist.ca/observations/17382285	Point Pelee National Park	9 October 2018	K. Yukich
H. agitator	iNaturalist	https://inaturalist.ca/observations/32570178	Point Pelee National Park	11 September 2019	K. Holloway
H. agitator	iNaturalist	https://inaturalist.ca/observations/32548831 and https://inaturalist.ca/observations/32548759	Point Pelee National Park	11 September 2019	J. Bensette
H. agitator	iNaturalist	https://inaturalist.ca/observations/32739266	Point Pelee National Park	14 September 2019	K. Yukich
H. agitator	iNaturalist	https://inaturalist.ca/observations/33167313	Point Pelee National Park	21 September 2019	D. MacNeal
H. agitator	iNaturalist	https://inaturalist.ca/observations/34168514	Pelee Isalnd	10 October 2019	R. Wood
Phyllopalpus pulchellus	iNaturalist	https://inaturalist.ca/observations/16506761	Amherstburg	13 September 2018	R. Jones
P. pulchellus	Facebook	post on "The Insects and Arachnids of Ontario" group	Amherstburg	13 September 2018	R. Parent
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/30439250	Ojibway Prairie Provincial Nature Reserve	6 August 2019	S.M. Paiero
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/30986390	Malden	16 August 2019	G. Pekor
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/31325743	Amherstburg	22 August 2019	R. Jones
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/32284331	Ojibway Nature Reserve	23 August 2019	G. Fowler
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/31426702, https://inaturalist.ca/observations/31574341, and https://inaturalist.ca/observations/31441348	Amherstburg	24 August 2019	J. McGuire and S. McGuire
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/31671581 and https://inaturalist.ca/observations/31671017	Malden	26 August 2019	T. Preney
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/31958808	Amherstburg	31 August 2019	R. Jones
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/32381873	Amherstburg	8 September 2019	R. Jones
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/32481132	Amherstburg	10 September 2019	"maygin2019"
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/32652284	Amherstburg	13 September 2019	"maygin2019"
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/32853810	Windsor	16 September 2019	T. Preney
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/33329351	Malden	22 September 2019	G. Pekor
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/33923010	Malden	5 October 2019	J. Hennin
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/34161242	Malden	7 October 2019	T. Preney
P. pulchellus	iNaturalist	https://inaturalist.ca/observations/34231994	Windsor	11 October 2019	G. Fowler

FIGURE 1. First posted observations of (A) *Phyllopalus pulchellus* Uhler (source: https://inaturalist.ca/observations/16506761) and (B) *Hapithus agitator* Uhler (source: https://inaturalist.ca/observations/16722342) in Canada on iNaturalist (iNaturalist.ca).

***Hapithus agitator* Uhler – restless bush cricket**

This distinctive cricket (Fig. 1B) was originally observed at two different sites on Pelee Island in September 2018 and was subsequently found at Point Pelee National Park in September and October 2018 (see Table 1). Two of the observations noted additional individuals in the immediate area, suggesting that *H. agitator* may be abundant in these areas and neighbouring sites. It appears to be locally common on the Nature Conservancy of Canada's Florian Diamante Nature Reserve on Pelee Island and has since been casually observed there by JCC. *Hapithus agitator* is known from neighbouring Ohio and Michigan (Bland 2003), so it is not surprising that it is found in adjacent parts of southwestern Ontario. This species was observed on the foliage of various plants, but can rapidly jump and find cover when disturbed. This is the second member of *Hapithus* to be recorded from Ontario, but the other species, *Hapithus saltator* (Uhler) (previously listed as *Orocharis saltator* Uhler; see Gorochov 2017), remains tentatively recorded in Ontario only from Brant County (Paiero and Marshall 2014), although it is now recorded from nearby Michigan (O'Brien and O'Brien 2015) and New York (Woo 2019).

These two new records increase Ontario's known cricket fauna to 25 species and the provincial Orthoptera fauna to 136 following the checklist of Paiero and Marshall (2014). Previous efforts to document the Ontario Orthoptera species with active survey efforts and the examination of records on online platforms, such as iNaturalist (www.inaturalist.org) and BugGuide (https://bugguide.net), suggest that these two new records represent relatively recent arrivals. Surveys at Point Pelee National Park (University of Guelph Insect Collection 2009a), Ojibway Prairie Provincial Nature Reserve (Paiero *et al.* 2010), Pelee Island (University of Guelph Insect Collection 2009b), and casual collections in southwestern Ontario (including night collections) over the past two decades would likely have encountered these distinctive species if they had been present, especially as Orthoptera were a target group. As both species are relatively conspicuous, it is also unlikely they would have been previously undetected by the strong naturalist community in southwestern Ontario, although they will certainly be noted as the populations grow and potentially expand into adjacent regions as seen in the 2019 data for both species. Additional Orthoptera species are likely to be found in southern Ontario as species recorded in nearby Michigan (Bland 2003) and Ohio (Walker 2018) may eventually expand their ranges into southern Ontario, if they do not occur there already. This northward expansion has also been noted for other katydids and crickets in the northeastern U.S.A. (Rainsong 2019) and may represent availability of habitat corridors and/or change of environmental conditions. With the increasing use of citizen science platforms to explore, document, and catalog species in the field, it will not be surprising if these new distributional records of Orthoptera will be documented there. Orthoptera is an ideal taxon for these platforms as the species are large enough for the characters important for their identification to be seen in photographs taken with most cellular phones and other portable digital devices. While some species are only separable by their songs, such as some *Oecanthus* (Gryllidae), these songs too can be captured on most handheld devices. The value of these platforms should also not be overlooked as a means to facilitate research, education, and develop ties and collaborations between researchers and the naturalist communities. Acorn (2017) discusses the benefits and issues that citizen science has in general for entomology in Canada, and the general success that it has had so far. In large taxa, such as Orthoptera, the value is already appreciable here.

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THE FIRST EASTERN NORTH AMERICAN RECORDS FOR THE INTRODUCED EUROPEAN RHYPAROCHROMIDS *DRYMUS BRUNNEUS* (SAHLBERG) AND *RAGLIUS ALBOACUMINATUS* (GOEZE), AND AN ADDITIONAL RECORD OF *GASTRODES GROSSIPES* (DEGEER) IN NORTH AMERICA

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The European rhyparochromid species *Raglius alboacuminatus* (Goeze) and *Drymus brunneus* (Sahlberg) have both been introduced into western North America, where they are now established in several states and provinces. A third European rhyparochromid species, *Gastrodes grossipes* (DeGeer), was previously intercepted in shipments from Europe to Ontario, and was not previously thought to have been established in North America. Based on collections in southern Ontario, we here report *D. brunneus* and *R. alboacuminatus* as established in eastern North America; *G. grossipes* is recorded for the second time in Canada but is not yet known to be established. The known natural history of the three species is briefly reviewed.

Material examined includes specimens from the following collections: University of Guelph Insect Collection, Guelph, Ontario (DEBU); Canadian Centre for DNA Barcoding, Guelph, Ontario (CCDB); and the Canadian National Collection of Insects, Ottawa, Ontario (CNCI).

***Drymus brunneus* (Sahlberg) (Fig. 1)**

Drymus brunneus was originally recorded in North America from British Columbia by Scudder and Foottit (2006), and had not been recorded elsewhere in North America until specimens were found in Ontario. The presence of *D. brunneus* in Ontario was originally based on collections and observations from 2017 to 2019 by SPL in a suburban woodlot in Richmond Hill. Individuals were found by roughly shaking leaf litter (to dislodge any insects within the sample) over a small container and were found largely associated with alder

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(*Almus* Miller; Betulaceae) and birch (*Betula* L.; Betulaceae) stumps, which is consistent with collections by Scudder *et al*. (2011). Most occurred just above the soil level in moist leaf litter, as also noted by Bantock and Botting (2018). Attempts to collect other individuals at the same site in 2018 were unsuccessful due to the prevalence of invasive European Fire Ants (*Myrmica rubra* L.; Hymenoptera: Formicidae). Examination of the Barcode of Life Database (www.boldsystems.org) found additional specimens, including those with photo vouchers, that had been collected in the Rouge National Urban Park in 2013. They had been identified in 2015 using barcode comparisons with sequenced European specimens of *D. brunneus*, but their significance was not noted at that time.

Specimens examined: ONTARIO: York Reg.: Richmond Hill, Horner Park, 17 May 2017, S.P.L. Luk (1 male; DEBU). Richmond Hill, Horner Park, 5 May 2019, leaf litter, S.P.L. Luk (3 males, 4 females; DEBU). Rouge National Urban Park, W of Glen Rouge Campground, 43.804 -79.146, pitfall traps in marsh scrub along riverside, 9 June 2013, BioBUS 2013 (2 adults; CCDB). Rouge National Urban Park, N of Kingston Road, 43.808 -79.137, along slope nr Rouge River, pitfall trap, 9 June 2013, BioBUS 2013 (13 nymphs; CCDB).

FIGURE 1. *Drymus brunneus* (Sahlberg) from Richmond Hill, Ontario, in 2017.

***Gastrodes grossipes* (DeGeer) (Fig. 2)**

We here record an additional record of the European *Gastrodes grossipes* in Ontario and speculate on its occurrence in Ontario. Maw *et al*. (2000) recorded this species in Ontario as an interception based on specimens taken from a shipment at the Ottawa International Airport in 1989. No other published reports of it becoming established in North America are known. In April 2019, one female was collected from Cambridge on the side of a building without any specific plant association and was identified with Usinger (1938). As this species is known to feed on pine (*Pinus* L.; Pinaceae) (Bantock and Botting 2018), samples of leaf litter and partially opened cones were made in nearby pine stands in June 2019 and April 2020, along with sampling from the single pine tree on the neighbouring property, but no additional specimens were found. The only other conifer near the original collection site was a spruce (*Picea* Miller; Pinaceae), but *G. grossipes* is not known to feed on spruces, although they are recorded as overwintering in spruce cones (del Favero and Masutti 1974). Collections of *G. grossipes* in Italy suggest that it is commonly encountered in *Pinus* cones, along with being a suspected vector of tip blight (*Sphaeropsis sapinea* (Fr.) Dyko & B. Sutton; Feci *et al*. 2003). Further directed sampling is required to determine if this species has become established in Ontario or if this was a serendipitous collection of an adventitious specimen.

FIGURE 2. Dorsal and ventral views of *Gastrodes grossipes* (DeGeer) collected from Cambridge, Ontario, in 2019.

A second species of *Gastrodes*, *G. walleyi* Usinger was described from Ottawa (Usinger 1938), based on a single damaged male collected on 1 July 1914, and has not been collected in Ontario since. It can be separated from *G. grossipes* and other *Gastrodes* by the apically bifid femoral spine (Usinger 1938), although the female is unknown. Slater and Brailovsky (1997) record it in British Columbia but do not provide further details, it is not noted to occur from there in Ashlock and Slater (1988) or Maw *et al*. (2000), and efforts to find associated specimens were unsuccessful. The omission by the latter references may suggest the specimen had been misidentified and/or may have represented an overlooked record that was not known in 1988. In North America, this genus is otherwise only known from the west (Ashlock and Slater 1988; Slater and Brailovsky 1997) with the exception of *G. grossipes*.

Specimens examined: ONTARIO: Ottawa, International Airport, from confiscated pine and spruce cones from Switzerland, emerged in lab, 23.v.1989, [no collector given] (2 males; CNCI). Waterloo Reg., Cambridge, April 2019, S.M. Paiero (1 female; DEBU).

***Raglius alboacuminatus* (Goeze) (Fig. 3)**

Raglius alboacuminatus was first reported in North America from Utah in 1999 and subsequently collected in California in the following few years (Henry 2004). It has since spread into Oregon and Washington (LaGasa and Murray 2007), and British Columbia (Acheampong *et al*. 2016). It is here recorded as established in Ontario. In August 2016,

FIGURE 3. *Raglius alboacuminatus* (Goeze) from Grimsby, Ontario, in 2016.

a private landowner in Grimsby contacted OMAFRA due to an abundance of an insect, subsequently identified as *R. alboacuminatus*, on their land and around an adjacent winery, and an image was submitted for identification. The image had been posted to Pest Control Canada, with the specimen provisionally identified as *R. alboacuminatus* by E. Saugstad, and was forwarded to SMP for confirmation. A visit to the site for voucher specimens confirmed the landowners' observations of abundance around their property; large numbers of *R. alboacuminatus* had fallen into the pool (along with many more that had been removed in the previous days by the owner) and were coming indoors and bothering the inhabitants as they slept. Other published accounts (Henry 2004; Acheampong *et al*. 2016; Bechinski and Merickel 2007; Masten Milek and Šimala 2010) indicate that the local abundance of individuals can make them nuisance pests, but they are not an agricultural crop pest. Additional trips to the region found specimens in St. Catharines; examination of iNaturalist (www.inaturalist.org) found a supplemental observation from St. Catharines. No other observations in eastern North America are currently known. Sampling in Guelph, Simcoe, Windsor, and Hamilton areas found no additional records so it is possible that this species is currently restricted in Ontario to the Niagara Region.

Henry (2004) summarized the known hosts, including *Stachys* L., *Marrubium* L., *Ballota* L. and "other Lamiaceae", and *Verbascum* L. and "other Scrophulariaceae"; Acheampong *et al*. (2016) note that the nymphs feed on Lamiaceae species but do not provide any specific examples. Although no specific hosts were noted in the original collection in Grimsby, it is very likely that one of several commonly used ground-cover or ornamental Lamiaceae species were in the nearby gardens. In St. Catharines, several individuals were found associated with red deadnettle (*Lamium purpureum* L.; Lamiaceae). One potential host, based on the broad host range, is the provincially endangered hoary mountain mint [*Pycnanthemum incanum* (L.) Michx.; Lamiaceae], which is known in Ontario from only two sites (Burlington and Hamilton) that are relatively short distances from where *R. alboacuminatus* is currently known; it is unclear what impact *R. alboacuminatus* may have on these populations when it finally reaches them.

This species has been referred to as the "tuxedo bug" by Bechinski and Merickel (2007), due to its black and white markings, but this could lead to some confusion with the plant bug genus *Tuxedo* Schuh (Hemiptera: Miridae), which is also similarly coloured (see Schuh 2004).

Specimens examined: ONTARIO: Niagara Reg.: Grimsby, 11 August 2016, S.M. Paiero (9 males, 9 females, 2 nymphs; DEBU). St. Catharines, 18 April 2019, "raptor310211" (iNaturalist observation 22668295). St. Catharines, Lakeshore Road & Niagara Street, ex. *Lamium purpureum*, 7 June 2019, S.M. Paiero (3 specimens; DEBU).

It is unclear if the eastern establishments of *D. brunneus* and *R. alboacuminatus* are introductions from established populations in western North America, or if secondary introductions from Europe to North America have occurred. The latter is possible for *R. alboacuminatus* as Dr. Thomas Henry (Smithsonian Institution, pers. comm.) noted that it has been regularly intercepted in the eastern U.S.A. in shipments from Europe. Based on the known hosts and habitat associations, both of these species would be expected to have a much broader range, both provincially and in eastern North America, and it is possible that these records represent only a portion of the current eastern range. Based on the available

material and search efforts, it appears *D. brunneus* and *R. alboacuminatus* have only recently become established in Ontario. It is expected that this range will increase; they may be accidentally carried to other parts of the province based simply on the numbers encountered at some of the sites sampled. As for *G. grossipes*, further sampling is needed to determine if this species has become established in eastern North America. Active search efforts in the Cambridge and Guelph areas have so far found no additional material, but perhaps it occurs at lower densities than those found in Europe. Regardless, further directed sampling will be needed to document the extent of these species in eastern Canada and the United States.

Acknowledgements

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FIRST CANADIAN RECORD AND ADDITIONAL NEW STATE RECORDS FOR NORTH AMERICAN DEER KEDS (DIPTERA: HIPPOBOSCIDAE: *LIPOPTENA CERVI* (LINNAEUS) AND *L. MAZAMAE* RONDANI)

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Abstract *J. ent. Soc. Ont.* 151: 33–40

Deer keds (Diptera: Hippoboscidae: *Lipoptena* Nitzsch and *Neolipoptena* Bequaert) are hematophagous ectoparasitic flies that primarily attack cervids and occasionally bite humans and companion animals. While a number of studies have reported half a dozen arthropod-borne pathogens in deer keds, it is unknown if they are competent vectors. In response to the increasing concern of deer keds as pathogen vectors, a recent study produced the first county-level map of deer keds in North America. Since that study was published, a number of new range records have come to light, including the first records for Canada as well as two new state/provincial, and 33 new county or provincial records for deer keds in eastern North America.

Introduction

Deer keds (Diptera: Hippoboscidae: *Lipoptena* Nitzsch and *Neolipoptena* Bequaert) are dorsoventrally flattened, blood-feeding ectoparasites that primarily attack cervids such as white-tailed deer (*Odocoileus virginianus* (Zimmermann)), moose (*Alces alces* (Linnaeus)), and elk (*Cervus canadensis* (Erxleben)), but also occasionally bite humans (*Homo sapiens* Linnaeus), dogs (*Canis lupus familiaris* Linnaeus), and other medium to large mammals (Skvarla & Machtinger 2019). Four species of deer keds occur in North

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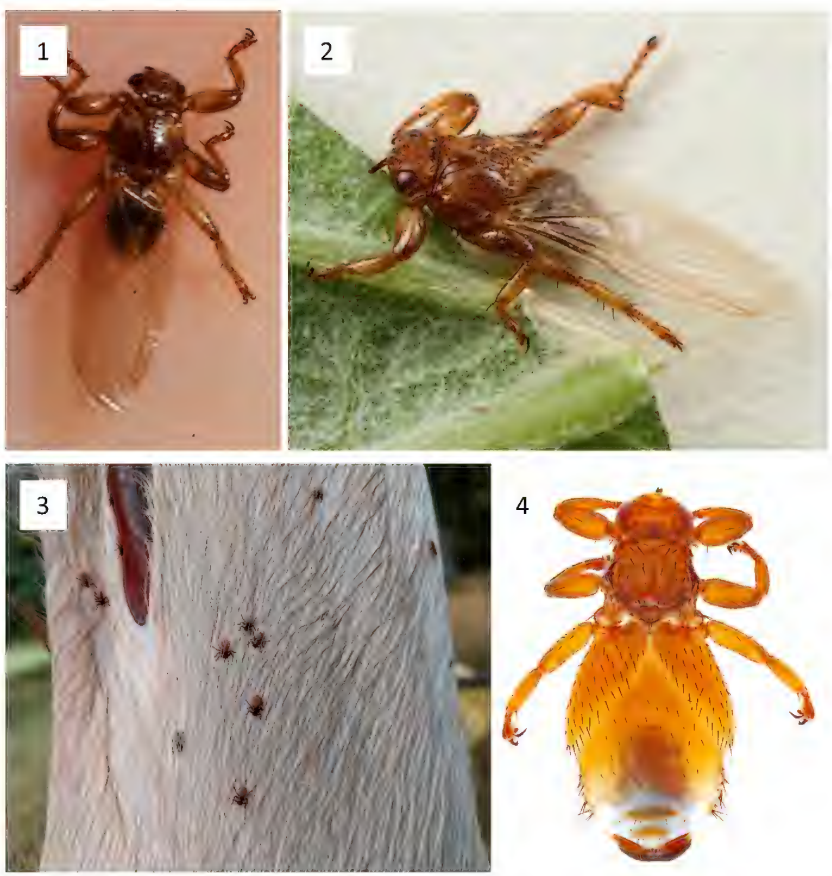
America. While *Lipoptena cervi* (Linnaeus) (Figs. 1, 2) were accidentally introduced from Europe, *L. depressa* (Say) (Figs. 3, 4), *L. mazamae* Rondani, and *Neolipoptena ferrisi* (Bequaert) are all native.

Deer keds have been observed to be a "constant annoyance to wild deer" (Kellogg *et al*. 1971) and may be more influential on deer grooming behavior than ticks (Heine *et al*. 2017). In northern Europe, they can become so abundant that they are considered an occupational hazard and may be associated with ked bite dermatitis (Chistyakov 1968,



FIGURES 1–4. Deer keds. 1, 2, *Lipoptena cervi* found in Hocking County, Ohio (photographs by Laura Stalder, used with permission); 3, *Lipoptena mazamae* on a hunter-harvested white-tailed deer in Hickman Co., Tennessee (note the abundance and obviousness of the keds, which were not altered and were photographed as they naturally occurred on the deer shortly after it was killed) (photograph by Ted Faust, used with permission); 4, dorsal habitus of *L. mazamae* (photograph by Matt Bertone, used with permission).

Laukkanen *et al*. 2005, Härkönen *et al*. 2009). While deer keds have been known to bite and annoy animals and humans, only recently has there been much interest in deer keds as pathogen vectors. Over the last decade, half-a-dozen arthropod-borne pathogens and parasites have been sequenced from deer keds, including *Anaplasma* (e.g., de Bruin *et al*. 2015, Buss *et al*. 2016), *Bartonella* (e.g., de Bruin *et al*. 2015, Izenour *et al*. 2020), and *Rickettsia* (e.g., Hornok *et al*. 2011, de Bruin *et al*., 2015) (see Table 1 in Skvarla & Machtinger 2019 for summary). While it is currently unknown if deer keds are competent pathogen vectors, the association of keds with pathogens has increased interest in deer keds nonetheless (Skvarla and Machtinger 2019, Antônio Bezerra-Santosa and Otranto 2020).

If deer keds are determined to be competent vectors of various arthropod-borne pathogens, accurately knowing where they occur will be an important consideration for mitigating the risk of deer ked bites and possible pathogen transmission. In response to this need, Skvarla and Machtinger (2019) produced a range map of North American deer keds based on museum specimens and digitized specimen data, community science websites, and local collecting efforts. After publication, additional deer ked records that represent new county, state, and country records were identified through additional collections and community science websites and are presented here.

Materials and Methods

Museum abbreviations follow Evenhuis (2020) as follows: Frost Entomological Museum (PSUC) and Los Angeles County Museum of Natural History (LACM).

Specimens from Pennsylvania were collected using the protocol outlined by Poh *et al*. (2020). Specimens from Tennessee were collected from hunter-harvested deer, either by RB with the Tennessee Wildlife Resource Agency or by Ted Faust from deer he harvested. Vouchers of Pennsylvania and Tennessee keds were deposited in the PSUC. Specimens from Canada were collected when winged keds landed on the authors of the present study and will be deposited in the University of Guelph Insect Collection. Specimens from Ohio (Figs. 1, 2) are deposited in LACM. Additional photographic records were gathered from iNaturalist (www.inaturalist.org) and a single unconfirmed record was reported via Twitter.

Results

Physical specimen records

Lipoptena cervi

CANADA: **Ontario**, Leeds and the Thousand Islands, 44.363017, -76.054322, *ex* human. 8 October 2019, col. M.V.A. Burrell, C.D. Jones, D.A. Sutherland, S.R. Brinker, H. Pacheco • same data as preceding, except 44.358009, -76.062677 • UNITED STATES: **Maryland**, Garrett Co., *ex* hunter-harvested white-tailed deer, 30 October 2019, col. M. Skvarla, K. Poh, J. Evans • **Ohio**, Hocking Co., *ex* human hunter sitting in a tree stand, 2 November 2019, col. Phil Melilla via Lynn Faust • Hocking Co., Rockbridge, Clear Creek Metro Park, *ex* human, 28 October 2013, col. Laura Stalder Hughes, L. Faust •

Pennsylvania, Allegheny Co., Indiana township, *ex* hunter-harvested white-tailed deer, 30 November 2019, col. M. Skvarla • same data as preceding except West Deer township • Crawford Co., Athens township, *ex* hunter-harvested white-tailed deer, 31 October 2019, col. J. Gilbert • same data as preceding except 17 December 2019 • Erie Co., State Game Lands 155, *ex* hunter-harvested white-tailed deer, 5 October 2018 • Fayette Co., German township, *ex* hunter-harvested white-tailed deer, 7 December 2019, col. M. Skvarla • Green Co., Morris township, *ex* hunter-harvested white-tailed deer, 8 December 2019, col. col. M. Skvarla • Wyoming Co., Laceyville borough, *ex* hunter-harvested white-tailed deer, 1 November 2019, col. J. Taylor.

Lipoptena mazamae

UNITED STATES: **Tennessee**, Anderson Co., *ex* hunter-harvested white-tailed deer, 9 November 2019, col. R. Butler • same data as preceding except 23 November 2019 • same data as preceding except Blount Co., 9 November 2019 • same data as preceding except Campbell Co. • same data as preceding except Cumberland Co. • same data as preceding except Franklin Co., 23 November 2019 • same data as preceding except Johnson Co., 9 November 2019 • same data as preceding except Knox Co. • same data as preceding 23 November 2019 • same data as preceding except Loudon Co., 9 November 2019 • same data as preceding except 23 November 2019 • same data as preceding except 7 December 2019 • same data as preceding except 8 December 2019 • same data as preceding except Marion Co. • same data as preceding except Meigs Co., 9 November 2019 • same data as preceding except Monroe Co. • same data as preceding except Morgan Co. • same data as preceding except Perry Co., 23 November 2019 • same data as preceding except Roane Co., 9 November 2019 • same data as preceding except 23 November 2019 • same data as preceding except 7 December 2019 • same data as preceding except Smith Co., 9 November 2019 • same data as preceding except Union Co. • same data as preceding except 7 December 2019 • Hickman Co., Centerville, *ex* hunter-harvested white-tailed deer, 19 October 2019, col. T. Faust, L. Faust.

Digital specimen records

Lipoptena cervi

UNITED STATES: **Connecticut**, New London Co., *ex* human, 31 October 2019, obs. brisaidia, available online at https://www.inaturalist.org/observations/35150136 • **West Virginia**, Randolph Co., *ex* human, 25 October 2019, obs. Randybodkins, available online at https://www.inaturalist.org/observations/34889003.

Lipoptena mazamae

UNITED STATES: **Alabama**, Tuscaloosa Co., Elrod, Tulip Tree Springs, 9 October 2018, obs. jcabbott (J. C. Abbott), available online at https://www.inaturalist.org/observations/18689813 • **Georgia**, Baker Co., Joseph W. Jones Ecological Research Center, 10 April 2019, obs. joshuadoby (J. Doby), available online at https://www.inaturalist.org/observations/22305416 • **Mississippi**, Yalobusha Cp., 11 April 2019, obs. adfloyd, available online at https://www.inaturalist.org/observations/22374079 • **North Carolina**, Surry Co., Pilot Mountain State Park, *ex* white-tailed deer, 12 September 2018, obs. falyn (F. Owens),

available online at https://www.inaturalist.org/observations/16587374 ● **Texas**, Denton Co., Lewisville, Lewisville Lake Environmental Learning Area Nature Preserve, at moth light, 27 April 2019, obs. sambiology (S. Kieschnick), available online at https://www.inaturalist.org/observations/24302559.

New records

In total, we found one new national, two new state/provincial, and 33 new county records (Fig. 5). An additional unverified record likely represents a new state record.

Lipoptena cervi is newly reported from Canada (Ontario), Ohio (Hocking County), and Maryland (Garrett County), as well as the following counties in states with previously established records: New London (Connecticut) Allegheny, Crawford, Erie, Fayette, Greene and Wyoming (Pennsylvania), and Randolph (West Virginia).

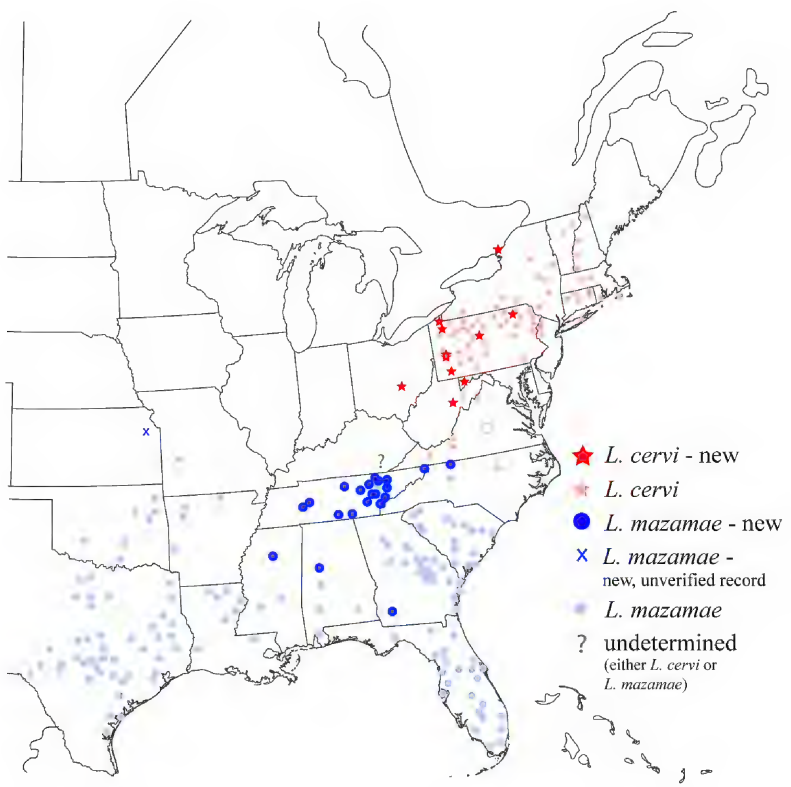


FIGURE 5. Range map of deer keds in eastern North America, modified from Skvarla & Machtinger (2019). Symbols for new range records presented herein are darker and larger than previously published records.

Lipoptena mazamae is newly reported in the following counties in states with previously established records: Tuscaloosa (Alabama), Baker (Georgia), Yalobusha (Mississippi), Surry (North Carolina), Anderson, Blount, Campbell, Cumberland, Franklin, Hickman, Johnson, Knox, Loudon, Marion, Meigs, Monroe, Morgan, Perry, Roane, Smith, and Union (Tennessee), and Denton (Texas).

Deer keds were also reported from Douglas County, Kansas on Twitter (https://twitter.com/StephenMBaca/status/1092530650853314562), but the authors have been unable to verify the identity of the specimens. If they are indeed deer keds, they are almost certainly *Lipoptena mazamae* based on the range and would be the most northern specimens of that species yet recorded.

Discussion

The deer ked occurrence map published by Skvarla and Machtinger (2019) was based mainly on museum specimens, with Pennsylvania records supplemented by local collecting efforts by the authors. However, deer keds are an understudied taxonomic group that are often uncommon in entomological collections, potentially due to their lack of economic and/or pest status. For example, before RB surveyed hunter-harvested deer in Tennessee, *L. mazamae* was only known from one locality in the entire state; after her survey, it is clear that they occur across wide swaths of, and likely the entire, state. Similarly, even though MJS and ETM screened hundreds of Pennsylvania deer for *L. cervi* in 2018, they found additional new county records when they screened hundreds of additional deer in 2019.

Considering this chronic under-surveying, it is difficult to define where the range edge of each species occurs. Still, it may be surprising that *L. cervi* was found in Ohio, more than 200 kilometers west of any previous collection record. Additionally, if *L. cervi* was introduced to North America in the late 1800s and given the uncertainty where keds occur, it is impossible to say whether this species has reached the full extent of their possible range in North America or if they are still expanding into new territory. Additional survey work and screening of deer on the perimeter of the known range, especially in eastern Ohio, West Virginia, eastern Kentucky, and southern Quebec, will help delimit where *L. cervi* occurs.

In northern Europe, *L. cervi* can become so abundant that they are viewed as an occupational hazard (Hackman *et al.* 1983, Laukkanen *et al.* 2005, Härkönen *et al.* 2009). In North America, similarly high populations have only been reported anecdotally across central and western Pennsylvania (MS pers. comm. with multiple hunters). JE discovered a potential hotspot when seven *L. cervi* landed on him and a colleague within the space of an hour in Pennsylvania State Game Lands 103 (Centre County) on 20 October 2020. In Ontario, more than 20 *L. cervi* landed on authors CDJ and MVAB during the course of a 6 km hike over a period of 5.5 hours. The presence of multiple ked "hotspots" across Pennsylvania and Ontario suggests the phenomenon may be more widespread than is currently recognized. It is unclear whether such high populations are a relatively new phenomenon in North America or just being reported for the first time.

If deer keds are shown to be competent vectors of tick-borne pathogens, it will be important to elucidate where exactly they occur and how their prevalence varies across their

ranges, how common deer ked "hotspots" are, and what environmental conditions cause "hotspots" to occur through additional survey work.

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FIRST CANADIAN RECORD OF THE SPECIALIST HIBISCUS BEE, *PTILOTHRIX BOMBIFORMIS* (CRESSON) (HYMENOPTERA: APIDAE)

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Ptilothrix Smith (Hymenoptera: Apidae) is a relatively uncommon, amphitropical genus in the Western Hemisphere with two described species in North America: *Ptilothrix bombiformis* (Cresson) (an eastern species occurring from Connecticut and New York west to Kansas, south to Texas and Florida), and *P. sumichrasti* (Cresson) (a south western species ranging from along the border of Arizona and New Mexico into Mexico and Guatemala) (Krombein *et al.* 1979; Michener 2007; Roig-Alsina 2007; GBIF 2020a; GBIF 2020b). As this genus has not previously been recorded in Canada, here we document the first Canadian occurrence records of the specialist Hibiscus bee *P. bombiformis*. Six female *P. bombiformis* specimens were collected from Ojibway Prairie Provincial Nature Reserve in Windsor, Ontario, a high-quality oak savannah remnant, in the late summer of 2018. We discuss the plant associations and preferred nesting substrates for this species and speculate that our records represent a recent range expansion into Canada.

Established in 1977, Ojibway Prairie Provincial Nature Reserve (42° 15'35.00"N, 83° 04'10.00"W), is a 65-hectare provincial park and one of the largest remnants of oak savannah in Canada (Szeicz and MacDonald 1991; Shorthouse 2010). The nature reserve is one part of the 350-hectare Ojibway Prairie Complex and, along with municipally operated Ojibway Park, Tallgrass Prairie Heritage Park, Spring Garden Natural Area, and Black Oak Heritage Park, is designated as an Area of Natural and Scientific Interest and a Carolinian Canada site of importance (Paiero *et al.* 2010; Ontario Ministry of Natural Resources 2015). The complex is a biodiversity hotspot where many rare plants and insects occur. In fact, it represents the northern range extension in the Nearctic of species such as *Olixon banksii* (Brues) (Hymenoptera: Rhopalosomatidae) and is the only known location of *Loxocera ojibwayensis* Buck (Diptera: Psilidae) (Buck and Marshall 2006; Paiero *et al.* 2010).

All *P. bombiformis* specimens were collected in blue-vane traps (SpringStar Inc.) during the late summer of 2018. Each sampling unit had one pan trap array with a yellow, blue, and white pan trap (White Plastic Solo Bowls (12 oz): either spray painted with Rustoleum Oasis Blue (code: 281002), or Rustoleum Gloss Sun Yellow (code: 253712) or left unpainted) placed on the ground, 3–5 m apart in a triangle pattern, and one blue-vane trap placed at a height of 1–2 m from the ground, 5 m from the pan trap array. A total

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of 20 blue-vane traps and 60 pan traps were deployed during each trapping session, each filled with a mixture of water and a few drops of unscented, biodegradable dish soap (blue circles in Fig. 1A). Traps were set in the morning and collected at the end of the day, twice a month from May to September. Trapping occurred throughout the park, but *P. bombiformis* specimens were only collected from two areas during two trapping sessions, once in July and once in August 2018 (yellow circles in Fig. 1A). Specimens were collected in an area of the nature reserve that is considered naturalized (Titcombe Park-north eastern side: Fig. 1B), and an area that has been restored through shrub removal (south western side: Fig. 1C).

Formerly placed in Anthophoridae: Anthophorini, *Ptilothrix* is now classified in the family Apidae: Emphorini (Michener 2007). Emphorini can be distinguished from other groups by the convex vertex, with ocelli below the margin of the head and short antennae in males (Michener 2007). In eastern North America, *Ptilothrix* can be identified using the keys to family and genus in Mitchell (1960, 1962, respectively). Specific characters include lack of arolia between tarsal claws; elongate first flagellomere, which is two or more times as long as its apical width; finely plumose and elongate hind tibial scopal hairs; both sexes with black clypeus; marginal cell acute apically and bent away from costal margin slightly; and three submarginal cells, with the second shorter than the first or third (Michener 1944; Mitchell 1962). *Ptilothrix bombiformis* are moderately large bees (body lengths: ♀ 13–17.5 mm, ♂ 12.5–17.5 mm, Mitchell 1962), with dense plumose pale hairs on the head and thorax, a black abdomen, and elongate finely plumose black scopa on hind legs (Fig. 2). At first glance they may be confused with bumble bees (*Bombus* spp. Latreille (Hymenoptera: Apidae)) or *Melissodes* spp. Latreille (Hymenoptera: Apidae) as they are similar in size and general appearance. Specimens were identified by J. K. Sharkey using the taxonomic key to North American bee families in Mitchell (1960), and then the corresponding key to genera in Mitchell (1962).

Specimen data: 1♀, Canada, ON, Essex Co., Ojibway PPNR, OJ-NA, Naturalized, 42°15'36.06"N, 83°3'41.52"W, BV1, 24.vii.2018, Raine Lab Collection, University of Guelph (RLCO): 70183, J. K. Sharkey and S. C. Irwin; 1♀, Canada, ON, Essex Co., Ojibway PPNR, OJ-RS, Restored, 42°15'14.11"N, 83°4'32.08"W, BV3, 14.viii.2018, RLCO: 69781, J. K. Sharkey and S. C. Irwin; 1♀, Canada, ON, Essex Co., Ojibway PPNR, OJ-NA, Naturalized, 42°15'32.15"N, 83°3'40.91"W, BV3, 24.vii.2018, RLCO: 69912, J. K. Sharkey and S. C. Irwin; 1♀, Canada, ON, Essex Co., Ojibway PPNR, OJ-RS, Restored, 42°15'17.25"N, 83°4'30.7"W, BV1, 14.viii.2018, RLCO: 69765, J. K. Sharkey and S. C. Irwin; 1♀, Canada, ON, Essex Co., Ojibway PPNR, OJ-NA, Naturalized, 42°15'35.44"N, 83°3'38.27"W, BV5, 14.viii.2018, RLCO: 69830, J. K. Sharkey and S. C. Irwin; 1♀, Canada, ON, Essex Co., Ojibway PPNR, OJ-NA, Naturalized, 42°15'32.15"N, 83°3'40.91"W, BV3, 24.vii.2018, RLCO: 69910, J. K. Sharkey and S. C. Irwin [Four specimens (RLCO: 69765; RLCO: 69830; RLCO: 69910; RLCO: 69912) are deposited in RLCO and two specimens (RLCO: 69781; RLCO: 70183) have been deposited in the University of Guelph Insect Collection (DEBU), University of Guelph, Guelph, Ontario]. These records are archived with Canadensys (http://community.canadensys.net/) under resource title "First Canadian record of *Ptilothrix bombiformis* (Cresson) (Hymenoptera: Apidae)" and can be accessed here: https://doi.org/10.5886/rw80rv (Sharkey 2020).

FIGURE 1. (A) Map of study area and collection locations of *Ptilothrix bombiformis* in Ojibway Prairie Provincial Nature Reserve, Windsor, Ontario, Canada. Landscape photos of trapping locations of specimen records from (B) naturalized area (north-east corner); (C) restored area (south-west corner).

Plant associations

Emphorine bees are oligolectic pollen specialists, primarily at the species level, feeding on one, or a few, closely related plant species (Linsley *et al.* 1956; Michener 2007). *Ptilothrix* species specialize on pollen from flowers with deep corollas, and in the wild, *P. bombiformis* is known to collect pollen exclusively from *Hibiscus* L. (Malvaceae) (Michener 2007); although, it has also been observed collecting pure pollen loads from wild potato vine, *Ipomoea pandurata* L. (Convolvulaceae) during controlled experiments

FIGURE 2. *Ptilothrix bombiformis*, female (specimen RLCO: 70183) (A) dorsal view; (B) head, anterior view; and (C) habitus, lateral view.

(Simpson 2009). Swamp rose-mallow, *Hibiscus moscheutos* L. (Malvaceae), is the only native *Hibiscus* species found in Canada and is a species of special concern under the Species at Risk Act (COSEWIC 2004). It is typically restricted to remnant wetlands, coastal and deep water *Typha* L. (Typhaceae) marshes of Lake Erie, Lake Ontario, and Lake St. Clair and their connecting waterways (COSEWIC 2004; Environment Canada 2013), and has been recorded from the Ojibway Prairie Complex and surrounding areas (Pratt 2018). Non-native *Hibiscus* species, such as naturalized *H. trionum* L. (GBIF 2020c) and horticultural *H. syriacus* L. (also known as rose of Sharon), are found in abundance in the area (J. K. Sharkey, Pers. Obs.). Another potential forage plant, *I. pandurata,* is critically endangered in Canada, and is only found from one area in Essex County (Oldham and Brinker 2009). It is possible that *P. bombiformis* is collecting pollen from these plants, or the many species of non-native morning glory (*Ipomoea* L. spp.) instead of, or as well as, the native species.

Ptilothrix bombiformis has been observed visiting *Althaea* L. (Malvaceae), *Cephalanthus* L. (Rubiaceae), *Cirsium* Mill. (Asteraceae), *Verbena* L. (Verbenaceae), and *Vernonia* Schreb. (Asteraceae) flowers for nectar (Krombein *et al.* 1979). Several of these plants, including buttonbush (*Cephalanthus occidentalis* L.), ironweed (*Vernonia* spp.), thistle (*Cirsium* spp.) and vervain (*Verbena* spp.) are found in the Ojibway Prairie Provincial Nature Reserve (Pratt 2005; J. K. Sharkey, Pers. Obs.). In a recent paper, *P. bombiformis* were collected from commercial cotton fields *Gossypium hirsutum* L. (Malvaceae) in Mississippi, suggesting that they may also visit flowers of this genus closely related to *Hibiscus* (Parys *et al.* 2020).

Nesting behaviour

Ptilothrix bombiformis is a ground nesting bee, often referred to as a chimney bee due to the turret-like structures it constructs at nest openings (Michener 1947; Rust 1980; Roig-Alsina 2007). Nests may be aggregated and are found in hard, compacted soils, such as roadsides and berms (Grossbeck 1911; Rust 1980). Although nesting sites are commonly found in compacted soil, they are usually close to permanent standing water (such as wetlands) as *P. bombiformis* have a unique behaviour of landing on water to collect it to soften soil for excavation and cell construction (Robertson 1890; Robertson 1925; Michener 2007). *Ptilothrix bombiformis* are known to be active towards the end of the summer during host plant bloom periods, when females collect pollen and males guard host plant flowers (Rust 1980).

Conclusions

Given that *P. bombiformis* has not been found by historical insect sampling in oak savannah and tallgrass communities in southern Ontario (Sugar *et al.* 1998; Richards *et al.* 2011; Pindar 2013) or extensive sampling specifically in Ojibway Prairie Provincial Nature Reserve (Skevington *et al.* 2000; Paiero and Buck 2003; Paiero *et al.* 2010), it is likely that our records represent a recent range expansion. We recommend further investigation into the occurrence and range of this species, particularly in areas of suitable habitat near Lake St. Clair and the northern shore of Lake Erie, from Windsor to Fort Erie, as well as investigating nesting locations and food plants around the known occurrence location.

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